University of Cambridge

SOLAR PHYSICS OBSERVATORY

SIXTH ANNUAL REPORT OF THE DIRECTOR OF THE SOLAR PHYSICS OBSERVATORY TO THE SOLAR PHYSICS COMMITTEE

1918 APRIL 1—1919 MARCH 31

Sixth Annual Report of the Director of the Solar Physics Observatory

21 *May* 1919.

The VICE-CHANCELLOR begs leave to publish to the Senate the following Report which the Solar Physics Committee have received from the Director of the Solar Physics Observatory:

The Report here presented relates to the year 1918 April 1 to 1919 March 31.

The year ends in the happy circumstances of the return of many of the Staff, who have been engaged in the war.

The Assistant-Director, Mr Stratton, returned on February 17. He had been promoted on January 1 to the rank of Brevet-Lieutenant-Colonel for services in the field, and was mentioned, for the fifth time, in Field-Marshal Sir Douglas Haig's Despatch of last December. He has also been made a Chevalier of the Legion of Honour by the French Government.

The Second Junior Observer, Mr W. Moss, resigned his post as Assistant Inspector of Optical Supplies at Woolwich Arsenal soon after the Armistice was signed; and he returned to the Observatory on December 2. The Resident Attendant, W. H. Manning, resumed work on December 9.

The First Junior Observer, Mr W. E. Rolston, is now the only absent member of the Staff; he is still with the Army of Occupation at Cologne.

Recent information gives hope that the apparatus taken to the Crimea in July 1914 was intact in the Custom House at Odessa in March 1919.

A. *Stellar Work.*

In continuation of the work on the classification of stellar spectra, the photographs available at Cambridge of stellar spectra assigned in the Harvard Classification to types F to Mb have been studied, and arranged in a continuous sequence in relation to the intensities of characteristic lines of different chemical elements.

Spectra assigned in the Harvard classification to types A_0—A_9 have been similarly studied and arranged in what appears to be the best sequence, as based on various criteria, such as the prominence of the K line of calcium, the enhanced line of iron at λ 4233, the arc line of iron at λ 4045, and in a few cases the helium lines at $\lambda\lambda$ 4026 and 4471. It is found in the material available that the spectra included by the Harvard observers in type A_0 differ considerably from one another, the only constant feature being the strength and breadth of the hydrogen lines. They can be divided into two fairly definite groups.

A revision has been made of a paper, prepared at South Kensington and published in 1914, on the lines of unknown origin in celestial spectra. Lines, which since the publication of that paper have been traced to their chemical origin, have been eliminated, and other lines of origin still unknown have been added.

The wave lengths of bright lines recorded in the difficult and complex region between λ 4600 and λ 4650 in various celestial spectra have been tabulated. The different wave lengths recorded appear at first sight to involve 30 or 40 separate lines, but on careful scrutiny it is found probable that not more than 6 or 7 lines are really involved in this complex region.

The above stellar work has been in the charge of Mr Baxandall.

Observations of the brilliant new star which was discovered in the constellation of Aquila on 1918 June 8, were begun on Sunday, June 9, on which day news of the outburst was received from the Astronomer Royal. Out of 35 photographic plates exposed in the new spectrograph attached to the 15-inch Huggins refractor, many contain valuable records of the changes in the spectrum of this very interesting Nova. The photographs obtained on June 13 and 15 have been studied in detail; and a note on some of the results was communicated to the Royal Astronomical Society in November (*Monthly Notices*, 79, 31). The conclusions drawn from this examination are that the outburst of Nova Aquilae was accompanied by changes in the spectrum which, if interpreted as indicating motion in the line of sight, involve two or more pulses moving with exceedingly high velocities. By observations on Nova Geminorum II in 1912 the Director and Mr Stratton were led to recognize that the narrow lines in the spectrum of that Nova were attributable to absorption of the same kind as that characteristic of α Cygni (*Monthly Notices*, 73, 380). From the observations

of Nova Aquilae III, the complex absorption lines exhibited in its spectrum have been deciphered as being effects characteristic of α Cygni, but duplicated by two large displacements which agree with those of the simultaneously duplicated absorption lines of hydrogen.

The later photographs of this Nova obtained by Mr Butler and Mr Stanley are next to be measured and discussed: and Mr Stratton's recent work on Nova Geminorum II, referred to in the following paragraph, gives a new clue to the changes to be looked for in the spectrum of Nova Aquilae.

Since his return from active service abroad, Mr Stratton has been occupied in preparing for press the discussion of the spectrograms of Nova Geminorum II taken at Cambridge and at Allegheny in 1912—work interrupted in 1914. A preliminary note following on an earlier one published in 1913 has been published in the *Monthly Notices* of the Royal Astronomical Society entitled "Note on the absorption spectrum of Nova Gerninorum II, March 1912" (*Monthly Notices*, March 1919). In this paper it is shown that the displaced α Cygni absorption previously found in the spectrum of the Nova is at a later stage in the life of the Nova accompanied by absorption characteristic of a star of type *B* but with a different displacement. The prominent lines attributed to nitrogen, oxygen, helium and carbon and found in the spectrum of γ Orionis (of type *B*) are represented in the spectrum of the Nova by absorption lines displaced to the violet by the same fraction of their normal wave length as the violet component of the doubled absorption lines of hydrogen. A key has thus been found for the identification of details of the Nova spectrum, but fresh physical problems calling for interpretation in their turn have been opened up.

The completion of a new spectrograph to be attached to the Newall telescope is at once to be resumed.

New estimates for completing the staging required for the 3-foot Reflector have been obtained from Messrs T. Cooke and Son.

B. *Solar Work.*

Spectroheliograph. Photographs of the sun's disc in $K_{2,3,2}$ light have been obtained on 111 days (previous year, 161) and photographs of the prominences at the limb on 101 days (previous year, 153). The work has been in the charge of Mr Butler for the past two years: and Mr Moss has now resumed his share in it.

The solar activity as gauged by the criterion afforded by these records appears now to be on the decline in its 11-year cycle.

The 18-inch and 6-inch mirrors were dismounted on 1919 March 13, and were replaced on March 24 after being resilvered.

The remodelling of the spectroheliograph on new lines is now to be resumed.

The Director of the Kodaikanal Observatory has forwarded 338 spectroheliograms showing the solar disc in calcium $K_{2,3,2}$ light for the year 1918 January 1—December 31. Of the 27 days missed in the Kodaikanal records there are Cambridge records for 9 days.

Study of spectroheliograms. A preliminary examination of the Kodaikanal records has been made in search of evidence of systematic distribution of calcium flocculi. Many of the photographs have been oriented for accurate determinations of heliographic positions; and convenient appliances have now been attached to the smaller heliomicrometer of De la Rue for facilitating the process of marking the orientation on the numerous photographs available.

Photoheliograms. Daily photographs taken with the Dallmeyer photoheliograph at Dehra Dún have been received. The negatives are stored at the Science Museum, South Kensington. Positive prints on paper have also been received from Dehra Dûn, and are being mounted for comparison with spectroheliograms, which are enlarged on paper to the same scale. Since December, 560 enlargements have been made, and the working up of the considerable arrears is going on apace.

Spectra of sun-spots. Photographs to the number of 83 have been taken of the spectra of sun-spots and other features on the sun's surface. Some features relating to the displacement of lines over the umbrae of spots have been studied in detail.

The two 16-inch mirrors of the M^c^Clean solar instruments which were used for this work were resilvered in March.

Study of sun-spot records. The study of the areas and life-history of sun-spots from the Greenwich records 1889—1912 was resumed by Mr Moss in December. The gathered material has now been sifted, and the results will be discussed and prepared for publication.

The frequency of occurrence of groups of sun-spots in different solar latitudes has been reduced to tabular form by the Director with the assistance of his private secretary, Mrs Beech. The graphical representation of the frequency for the three 11-year cycles 1879—1913 affords suggestive evidence of new relations. The irregular proper motions of spots in solar longitude and latitude is being studied in connexion with Dr Hale's work on vertical motion.

Monochromatic solar images. A new method of obtaining monochromatic images of the sun was tried in the summer months, and a more careful trial is to be made in the coming summer.

C. *Meteorological Physics.*

Investigations on lightning discharges. Mr C. T. R. Wilson has completed the preparation of his memoir on investigations on lightning discharges and on the electric field of thunderstorms.

The observations discussed in the memoir were made by him at the Solar Physics Observatory, chiefly in the summer of 1917. The methods of measurement have been referred to in previous reports, the latest improvement being the provision of apparatus for giving a photographic trace of the electrometer readings. Rapid changes in the potential gradient, occupying less than one-tenth of a second, are recorded when desired.

The chief results may be summarised as follows:

The sudden change produced in the potential gradient by lightning discharges has been more often positive than negative, 528 cases of positive and 336 of negative discharges having been recorded.

The sudden changes of potential gradient have been in most cases single; but other records, consisting of two sudden changes in rapid succession, either of the same or opposite sign, have been obtained; and yet others, consisting of multiple changes succeeding one another usually at intervals of one or two tenths of a second.

The records of simple lightning discharges show a vertical portion of the trace indicating sudden destruction of electric field after the passage of a lightning discharge, followed generally by a characteristic recovery curve which in some cases approaches very closely to the logarithmic form.

The slope of the portion of the curve recorded immediately after a discharge is a measure of the rate at which the field is being re-established; in other words, the rate at which the separation of charges is taking place, or yet in other words, it is a measure of the vertical electric current through the cloud.

The initial rates of recovery which have been recorded after a lightning discharge correspond to the separation per second of charges ranging between $\frac{1}{30}$ and $\frac{20}{30}$ of that discharged by the lightning. The last named larger rate would indicate the passage of a current of the order of 10 amperes through the thunder cloud.

The distance between the place of observation and the lightning discharge was estimated from the time interval between lightning and thunder in about 120 cases.

The average change produced in the potential gradient by lightning discharge within 1 or 2 kilometres is of the order of 20,000 volts per metre; for discharges at a distance of 10 kilometres, it is of the order of 1000 volts per metre.

If F is the sudden change of the vertical electric force at the place of observation and l is the horizontal distance of the discharge, then for distant flashes Fl^3 is equal to the electric moment of the discharge, namely $2QH$, where Q is the quantity of electricity discharged and H the mean height through which it has been displaced. When l is not great compared with H, then Fl^3 is less than $2QH$; and the mean value of Fl^3 gives therefore a lower limit for the mean electric moment. The lower limit thus found is approximately the same for positive and negative discharges and is about $2{\cdot}5 \times 10^{16}$ in electrostatic C.G.S. units, i.e. about 80 coulomb-kilometres.

The curve which gives the mean value of F for different distances of positive discharges agrees approximately with that which would result from a discharge to earth of about 20 coulombs from a height of about 5 kilometres. Such a discharge may therefore be regarded as in this sense representing an average positive lightning flash. The electric moment of such average flashes is thus somewhat more than twice the minimum estimate stated above. The evidence which is available for the negative discharges suggests a considerably smaller height. The difference would be explained if it is supposed that negative discharges pass mainly between the earth and the positively charged lower portion of a cloud of negative polarity (top negative), while a considerable proportion of positive discharges pass between the earth and the upper negatively charged portions of such clouds.

The manner of variation of F with l seems to indicate that the charge that feeds a lightning discharge is not derived from an extended horizontal sheet but rather from a limited region in

which the horizontal and vertical dimensions are not very different. Accordingly the result is much the same as if the charge had been distributed symmetrically in a sphere and were consequently equivalent to a point charge. From the numerical values obtained in these investigations, a radius of the order of 300 or 400 metres can be assigned to the sphere; and an estimate of the maximum potential of the localised charge contained in it can be deduced. The value of the potential for the average case before a lightning discharge approaches 1000 million volts. This leads to an estimate of the energy dissipated in an average flash—between 10^9 and 10^{10} joules; in a severe storm the rate of dissipation of energy in lightning discharges may be of the order of 1000 kilowatts. Consideration of the water power which would be obtained if the rainfall of such a storm could be intercepted at a height of one or two kilometres shows that sufficient energy is available. A consideration of the effects which are likely to be produced by the radial electric force upon the droplets in the outer portions of a thunderhead as the sparking limit is approached, suggests an explanation of the mode of formation of "false cirrus" and of its relation to other phenomena.

The results obtained in these investigations have suggested a theory, which both accounts for many of the more important phenomena of thunderstorms, and relates them to those of fine-weather atmospheric electricity and of terrestrial magnetism. This theory adopts the assumption which the phenomena of terrestrial magnetism are generally held to require, viz. that considerable conductivity exists in the upper atmosphere; it further makes use of the existence of the great mobility, which, in accordance with the recent experiments of Wellisch and others, the carriers of negative electricity dragged out of this conducting layer would possess; and it also takes into account the effects at the ground of the electrical field of a thunder cloud or shower cloud. There appears to be no reason for assuming that the polarity of such clouds may not be of either sign. The theory accounts for the preponderance of positive lightning discharges, of positively charged rain and of negative potential gradients in showers.

The theory also accounts for the normal positive electrical potential gradient of fine weather regions.

According to the view adopted, thunder clouds and other clouds from which heavy rain is falling may be regarded as electrical generators by which electric currents are maintained between the earth and the conducting layer of the upper atmosphere; currents in the upward direction preponderating, on account of the great mobility of the carriers of negative electricity, and so maintaining the positive potential of the upper conducting layer and supplying the downward current in regions of fine weather.

The order of magnitude of the currents in thunderstorms, as indicated by the results of observations of lightning discharges, is such as to suggest the possibility of correlating the phenomena of atmospheric electricity with those of terrestrial magnetism.

The electric force produced in the upper atmosphere above a thunderstorm at the moment of the passage of a lightning discharge is generally great enough to be of importance not only as a source of ionisation but also as giving rise to cathode rays, positive rays, and X rays; the potentials available being in fact sufficient for the production of corpuscular rays of very high velocity.

The theory does not conflict with existing theories of terrestrial magnetism which are based upon the arrival of corpuscular and other radiations from the sun. It rather affords a suggestion that processes similar to those existing in terrestrial thunderstorms may themselves be the source of origination of the emission of such radiations from the sun.

Miscellaneous.

A number of valuable publications and reprints have been received in the course of the year, and the Director desires to record his grateful acknowledgments to the donors. A list of such donations is appended.

H. F. NEWALL.

SOLAR PHYSICS OBSERVATORY.
1919 *May* 15.

The Director gratefully acknowledges the receipt of the following works, which have been presented to the Library of the Solar Physics Observatory:

ASTRONOMY.

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